REMARKS

Applicant thanks the examiner again for the careful attention accorded the present application. Applicant is especially appreciative of the constructive criticism regarding the wording of the claims, particularly Claim 9. Accordingly, the applicant has amended the claims in a manner that clarifies the claims and removes any ambiguity in the wording. The amended Claim 9 now provides the best mode contemplated by applicant of carrying out the invention and is, in fact, the actual recipe that applicant uses in constructing an Enhanced Volume Phase Grating of the present invention.

Amended Claim 9 has also removed the new matter (the expressions for C_R and C_S) and has revised the expression for Δn so that it contains only terms that have been supported and disclosed by the specification. The term β is defined as the internal angle of diffraction (the angle of diffraction within the medium of the volume phase grating) and the terms s and p are defined as any two positive integers, so long as s > p. These are the same definitions of these parameters that appear in the specification. Any selection of values of these two integers will establish one E-VPG design for a given value of the internal angle of incidence, α. A second set of these integers will establish a second E-VPG design for the same value of α. The invention claimed by the applicant is any and all volume phase gratings whose design is based on the use of these integers, s and p, in the equations of claim 9 to establish the internal angle of diffraction, β, and the index modulation, Δn, of the medium for a given internal angle of incidence, α.

With these new amendments, Claim 9 is now in compliance with 35 U.S.C. 112 and 35 U.S.C. 132. The invention is well defined as a grating, or family of gratings, that is constructed using the novel equations established in Claim 9. The indefinite terms have all been defined.

The indefiniteness problem of Claims 12, 15, and 16 has been corrected by deleting the indefinite words. These claims are now in compliance with 35 U.S.C. 112.

Applicant's invention is now well defined in Claim 9 as any volume phase grating that is designed using the equations of Claim 9 to establish the key parameters of the grating, namely, the internal angle of diffraction, β, and the index modulation, Δn, for any given wavelength, λ, and given average refractive index, n, and given medium thickness, T, and any arbitrary value of the internal angle of incidence, α. Any volume phase grating designed in accordance with the recipe in Claim 9, and <u>only</u> such gratings, will have equal and maximum S and P diffraction efficiencies across the full wavelength range of a telecom band AND will have high dispersion - more than four times the dispersion of a conventional volume phase grating.

Resp nse to rejection under 35 U.S.C. 103 (a) - unpatentable due to prior art patents: Jannson et.al. (PN 5,026,131) and Kato, et. al. (PN 5,726,782)

While the Jannson prior art patent does discuss Bragg volume gratings, Jannson does not teach that the S and P diffraction efficiencies of a high dispersion volume phase grating are equal. His comment that "the TE and TM polarization components have roughly the same diffraction efficiency" (Column 11, lines 39 to 44) is valid only for low dispersion volume phase gratings, as will be shown in the following tutorial. The advantage (and the novelty) of applicant's invention is that the S and P diffraction efficiencies of applicant's Enhanced Volume Phase Grating are both identically equal and maximum in a high dispersion grating. The dispersion of an E-VPG is at least four times the dispersion of a conventional VPG and the S and P diffraction efficiencies are both nearly 100% across the full width of a telecom band. This is what makes applicant's invention so valuable in telecom applications.

In order to clarify this point, it is necessary to discuss the fundamental concepts that govern the dispersion and the S and P diffraction efficiencies of a volume phase grating. This discussion will make it clear that the S and P diffraction efficiencies of conventional volume phase gratings are "roughly the same" only for low dispersion volume phase gratings. The following tutorial is an attempt to present the necessary VPG fundamentals in a way that should convince the reader of the accuracy of the statements in the above paragraph, thereby leading the reader to the conclusion that the Jannson patent does not teach what is taught in the applicant's application.

If the examiner desires additional clarification, applicant would welcome the opportunity to discuss the subject matter at examiner's office and at her convenience.

Tutorial on Enhanced Volume Phase Gratings (E-VPG) and their performance relative to that of the conventional volume phase gratings discussed in the Jannson patent

The Enhanced Volume Phase Grating (E-VPG) is the first volume phase grating to provide nearly 100% diffraction efficiency for both S and P polarizations simultaneously in a high dispersion grating. Prior art volume phase gratings could provide S and P diffraction efficiencies that were roughly equal but only in a relatively low dispersion grating. The objective of the tutorial in the following pages is to clarify the distinction between the E-VPG and prior art volume phase gratings and to show that the E-VPG is an unanticipated technological advancement over the prior art in volume phase gratings.

We will first derive the relationship between the angle of diffraction and the dispersion of a diffraction grating. Then we will show the relationship between the angle of diffraction and the S and P diffraction efficiencies as obtained from the Kogelnik Coupled Wave Theory. These two results will show how the S and P diffraction

efficiencies of a volume phase grating can be roughly the same in a low dispersion grating. They will also reveal that the S and P diffraction efficiencies of a volume phase grating will, in general, be very different in a high dispersion volume phase grating and, in fact, one of them can be zero while the other is simultaneously 100%. This last result, which has been noted in a prior patent (PN 5,013,107), is clear evidence that the statement made by Jannson (PN 5,026,131 Column 11, lines 39 to 44), that the S and P diffraction efficiencies in a volume phase grating are roughly the same, is in general false and, as we will show, is only true for low dispersion volume phase gratings.

Finally we will show how the E-VPG, and only the E-VPG, provides maximum diffraction efficiency for both S and P polarizations simultaneously in a high dispersion volume phase grating and we will provide the necessary conditions under which this will occur.

It is important to note that there are two major sets of equations governing the performance of a volume phase grating. The first equation is the grating equation, which determines the angle of diffraction given the angle of incidence, the wavelength of the incident light and the grating period.

The second set of equations is obtained from the Kogelnik Coupled Wave Theory. This theory provides the S and P diffraction efficiencies of a volume phase grating for a given set of medium parameters - the average refractive index of the medium, the index modulation, the thickness of the medium, the grating period and the tilt of the internal Bragg surfaces. The Kogelnik theory is discussed in his original paper ("Coupled Wave Theory for Thick Hologram Gratings", Bell System Technical Journal, Vol. 48, No. 9, November 1969, pages 2909 to 2947).

We will discuss both sets of equations as we develop the relationship between diffraction efficiencies and dispersion.

Diffraction grating

A diffraction grating consists of a transparent or reflective medium on which, or within which, a periodic structure has been created. This periodic structure is most commonly a set of lines or grooves in the surface of the medium. In the early diffraction gratings, these grooves were created by removing material with a ruling engine. A cross section of such a ruled diffraction grating is shown in Fig. 1.

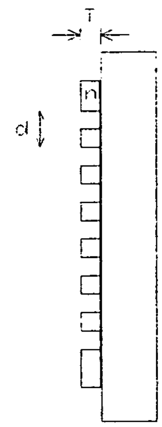

Fig. 1 Ruled diffraction grating

This ruled grating can be either a transmission grating, in which the medium is a transparent material, or it can be a reflection grating, in which the medium is a reflective material. In all of the following discussions, we will consider only transmission gratings.

The spacing of the grooves in the grating is called the grating period and is designated by the letter "d" in Fig. 1. The depth of the grooves is designated by the letter "T" and is generally referred to as the thickness of the grating.

Note that the refractive index, n, of the material is constant and the grating structure consists of a periodic variation in the thickness of the medium. This type of diffraction grating is called a surface relief grating. It is also possible to create a diffraction grating in which the grating structure consists of a periodic variation in the refractive index of the medium while the thickness remains constant. Such a diffraction grating is called a volume phase grating, or VPG. A cross-section of such a volume phase grating is shown in Fig. 2.

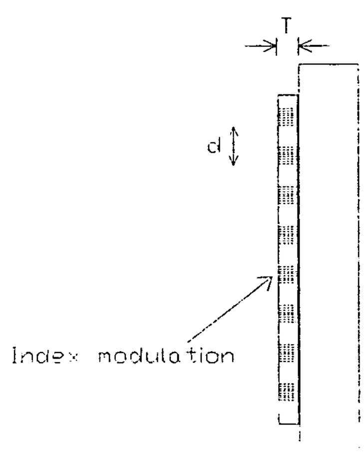

Fig. 2 Volume phase grating

When a transmission diffraction grating with period, d, is illuminated by a monochromatic light beam of wavelength, λ, at an angle of incidence, θ_i, where the angle of incidence is the angle between the incident beam and the normal to the grating surface (See Fig. 3), the angle of diffraction of the exiting beam, θ_d, is obtained from the Grating Equation:

(1) $$\frac{\lambda}{d} = \sin\theta_i + \sin\theta_d ,$$

where the angle of diffraction, θ_d, is the angle between the diffracted beam and the normal to the grating surface (See Fig. 3).

Here we are considering only the first-order diffracted beam since, in most telecom applications, that is the only order that will exist.

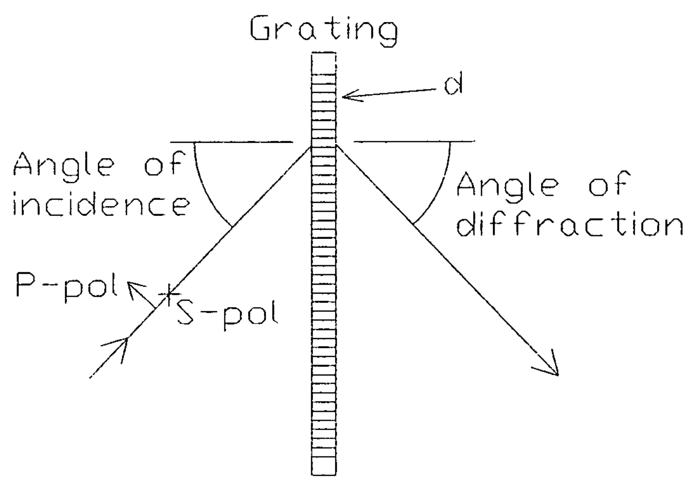

Fig. 3 Transmission diffraction grating showing the incident and diffracted beams

(Figure 3 also shows the directions of polarization for the S and P polarizations, for future reference. The direction of the S-polarization is into the paper in the figure)

Dispersion of a diffraction grating

The dispersion of a diffraction grating is defined as the variation of the angle of diffraction due to a variation in the wavelength of the incident beam, or $\frac{\Delta\theta_d}{\Delta\lambda}$.

(See Fig. 4)

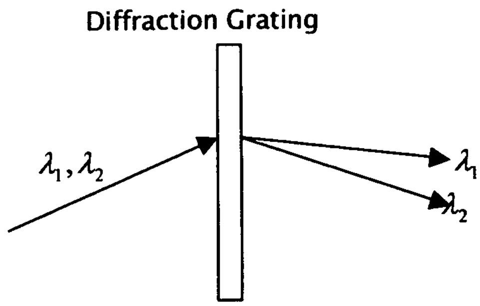

Fig. 4 Dispersion

Differentiating the grating equation we find that:

(2) $$\frac{\Delta\theta_d}{\Delta\lambda} = \frac{1}{d\cos\theta_d}$$

Substituting for d from the grating equation and reducing we get:

(3) $$\frac{\Delta\theta_d}{\Delta\lambda} = \frac{\sin\theta_i + \sin\theta_d}{\lambda\cos\theta_d}$$

In most cases of interest in telecom applications the angle of incidence will be the same as the angle of diffraction at the center wavelength of the telecom band. While this is not a requirement, by making this assumption we can simplify the discussion without any significant loss in generality. That is, we can set $\theta_i = \theta_d$ so that the above equation reduces to:

(4) $$\frac{\Delta\theta_d}{\Delta\lambda} = \frac{2\tan\theta_d}{\lambda},$$ which is plotted in the following figure:

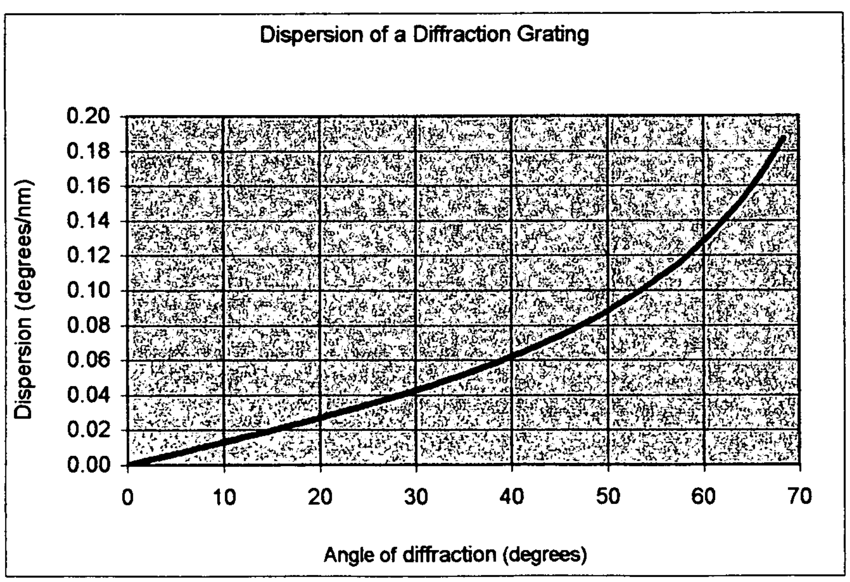

Fig. 5 Variation of dispersion with angle of diffraction

Fig. 5, which is a plot of Eq. (4), shows dispersion as a function of the angle of diffraction. Note that the dispersion increases as the angle of diffraction increases, and the rate of increase rises as the angle of diffraction becomes greater than 30 degrees. This is a major result that has significant impact on the use of diffraction gratings in telecom applications. This will become clearer in the following discussion.

Dispersion requirements for telecom applications

In telecom applications, very high levels of dispersion are required, particularly for the newer telecom systems, which are being designed for more channels than the present telecom systems. The advantages of higher dispersion can be seen by examining the following two figures.

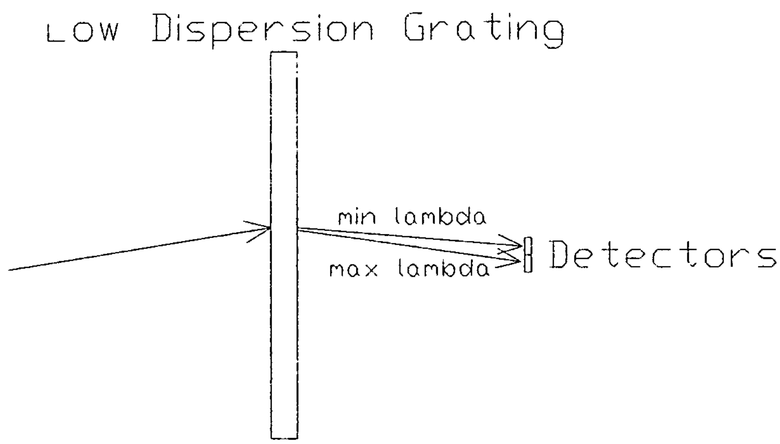

Fig. 6 Dispersion from a low dispersion diffraction grating

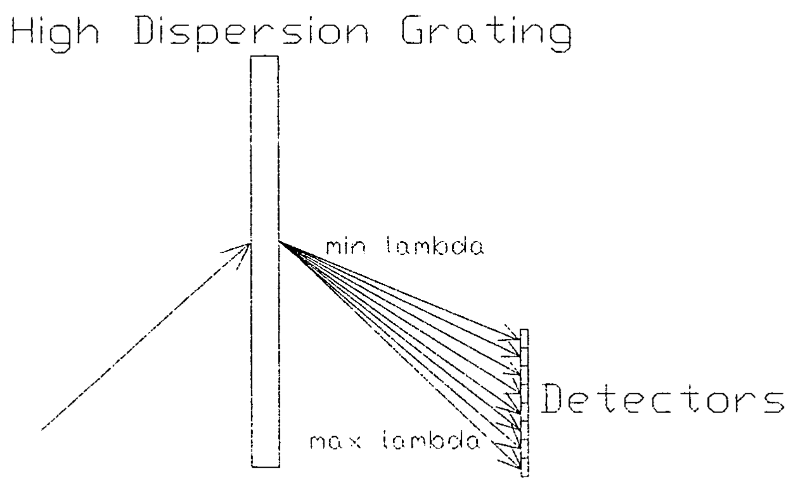

Fig. 7 Dispersion from a high dispersion diffraction grating

In both of these figures, the minimum wavelength (min lambda) and the maximum wavelength (max lambda) are the same. But the greater spread between the diffracted min lambda beam and the diffracted max lambda beam in the high dispersion grating means that we can add more channels for the same size and spacing of the detectors. This is why high dispersion is so important in telecom applications. The higher the dispersion, the greater the number of channels that can be handled. Therefore, in telecom systems we must use diffraction gratings with the maximum possible dispersion. And we now know, from Equation (4) and Fig. 5, that high dispersion can only be obtained by using large angles of incidence and diffraction.

There are other factors that must be considered, however, such as the diffraction efficiency of the grating and the dependence of the diffraction efficiency on the polarization of the incident beam. Those considerations are discussed in the following sections.

S and P diffraction efficiencies for a volume phase grating

In telecom applications, the polarization of the beam can vary as the beam propagates along the fiber. There is no way, at present, to eliminate this variation. If the diffraction efficiency of a diffraction grating used in a telecom system is strongly dependent on the polarization of the incident beam, then the signal strength will vary as the polarization varies. This variation in diffraction efficiency with polarization is called Polarization Dependent Loss, or PDL, and it is very detrimental in any telecom system. So it must be minimized. This is the reason why it is desirable to have equal S and P diffraction efficiencies in any grating that is to be used in a telecom application.

The S and P diffraction efficiencies for a transmission VPG are established by the equations in the paper by Kogelnik (Es on pages 2923 and 2924 and Ep in the appendix on pages 2943 to 2945). These equations are:

(5) $E_s = \sin^2 \upsilon$

(6) $E_p = \sin^2(\upsilon \cos(\alpha + \beta))$

where

(7) $$\upsilon = \frac{\pi \Delta n T}{\lambda \sqrt{(\cos\alpha)(\cos\alpha - \frac{\lambda}{nd}\tan(\frac{\beta - \alpha}{2}))}},$$

T = thickness of the VPG medium,

λ = free-space wavelength of the incident beam,

n = average refractive index of the VPG medium,

Δn = peak modulation of the refractive index of the VPG medium,
d = grating period (spacing between peaks of the index modulation),
α = angle of incidence of the incident beam inside the VPG medium,
β = angle of diffraction of the diffracted beam inside the VPG medium,
$\alpha + \beta$ = angle between the diffracted beam and the incident beam inside the VPG medium.

The angles α and β are related to the external angles of incidence and diffraction by Snell's law:

$\sin\theta_i = n\sin\alpha$ and $\sin\theta_d = n\sin\beta$.

If we consider the simplifying case where the angle of diffraction is equal to the angle of incidence, as we did in the previous section, then $\alpha = \beta$ and equation (7) reduces to:

(8) $$\upsilon = \frac{\pi\Delta nT}{\lambda\cos\alpha}$$

and equation (6) reduces to:

(9) $$E_p = \sin^2(\upsilon\cos2\alpha).$$

Note that the only difference between the equation for Ep (Eq. 9) and the equation for Es (Eq. 5) is the $\cos2\alpha$ term in the argument of the $\sin^2$ term for Ep. This is a critical factor. Recall that α is the angle of incidence (also the angle of diffraction in the equal-angle case) inside the VPG medium and note that 2α is the angle between the internal diffracted beam and the internal incident beam. Equation (9) tells us that for any given value of υ, the diffraction efficiency for the P-polarization will be <u>less</u> than the diffraction efficiency for the S polarization due to the $\cos2\alpha$ term in the expression for Ep. <u>And the difference between the two diffraction efficiencies will increase as the angles of incidence and diffraction increase</u>. The underlined sentence is significant since the angles of incidence and diffraction will be fairly large in any VPG intended for telecom applications in order for the VPG to provide a high degree of dispersion.

The following figures illustrate the key point in this discussion - that the S and P diffraction efficiencies of a transmission VPG can be roughly the same only if the angles of incidence and diffraction are small. But from the discussion of dispersion in the preceding sections, this means that <u>the S and P diffraction efficiencies of a transmission VPG can be roughly the same only for a low dispersion VPG</u>. Such a VPG is of little interest for telecom applications that require high dispersion.

The controllable VPG medium variables that determine the S and P diffraction efficiencies of a transmission VPG are the medium thickness, T, and the index modulation, Δn. In practice, T is generally fixed and the controllable variable is Δn. In the following figures, the S and P diffraction efficiencies are plotted as functions of the controllable variable Δn. The plots are essentially graphs of equations (5) and (9) for fixed values of wavelength and thickness. The external angle of diffraction, θ_d, is shown on each figure. This angle determines the internal angles of incidence and diffraction, α and β, through Snell's law, as already noted above.

In all of the following figures, the green vertical bar indicates a design value for the index modulation. This index modulation value is established during the exposure and processing of the VPG. Only one value of index modulation can be selected for any given VPG. It is not possible to select different values of index modulation for the two polarizations. In Figure 8, the design value for the index modulation is 0.049, which will result in high values for both Es and Ep, as can be seen in the figure.

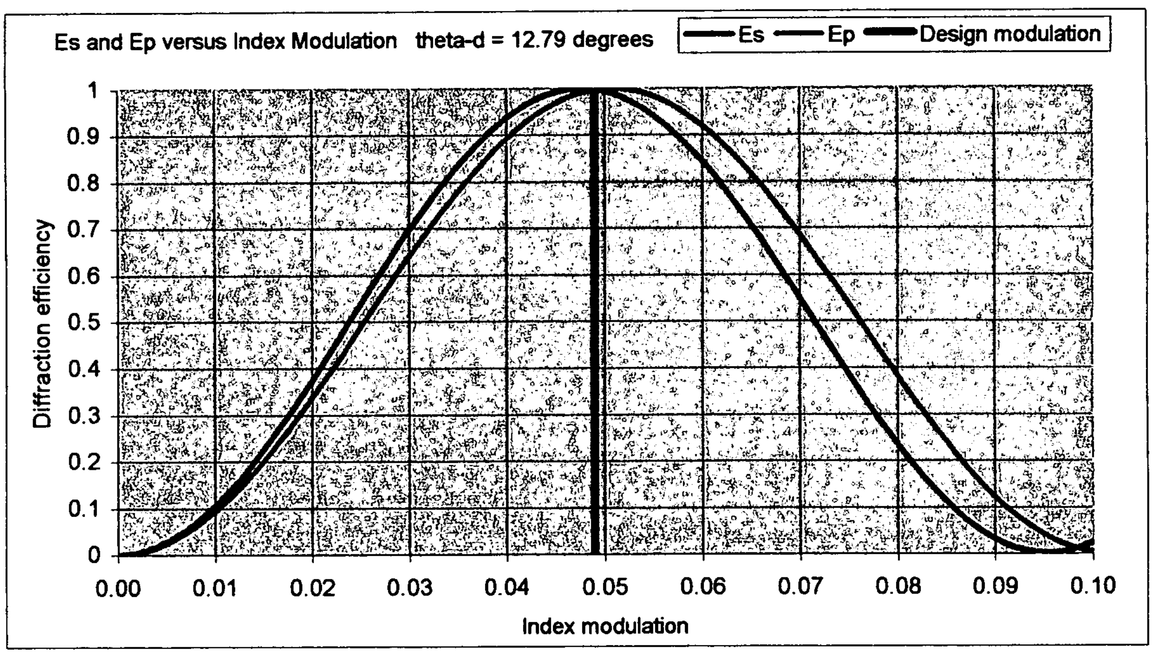

Fig. 8 S and P diffraction efficiencies versus index modulation in a low-dispersion transmission Volume Phase Grating

Figure 8 shows the variation of diffraction efficiency with index modulation for a low dispersion transmission VPG. The angle of diffraction for this case is 12.79 degrees, which will result in a dispersion of 0.01678 degrees/nm for a wavelength of 1550 nm, as obtained from the dispersion equation (Eq. (4) above). This is a relatively low value of dispersion.

Note that the S and P diffraction efficiencies are roughly the same for all values of index modulation and particularly near the peaks of the curves. This is the type of VPG for which Jannson's statement is valid. The S and P diffraction efficiencies are, as he notes, roughly the same. However, the dispersion will be low because of the small angle of diffraction.

Now, what happens when we try to increase the dispersion by increasing the angles of incidence and diffraction? Figure 9 shows the result of increasing these angles.

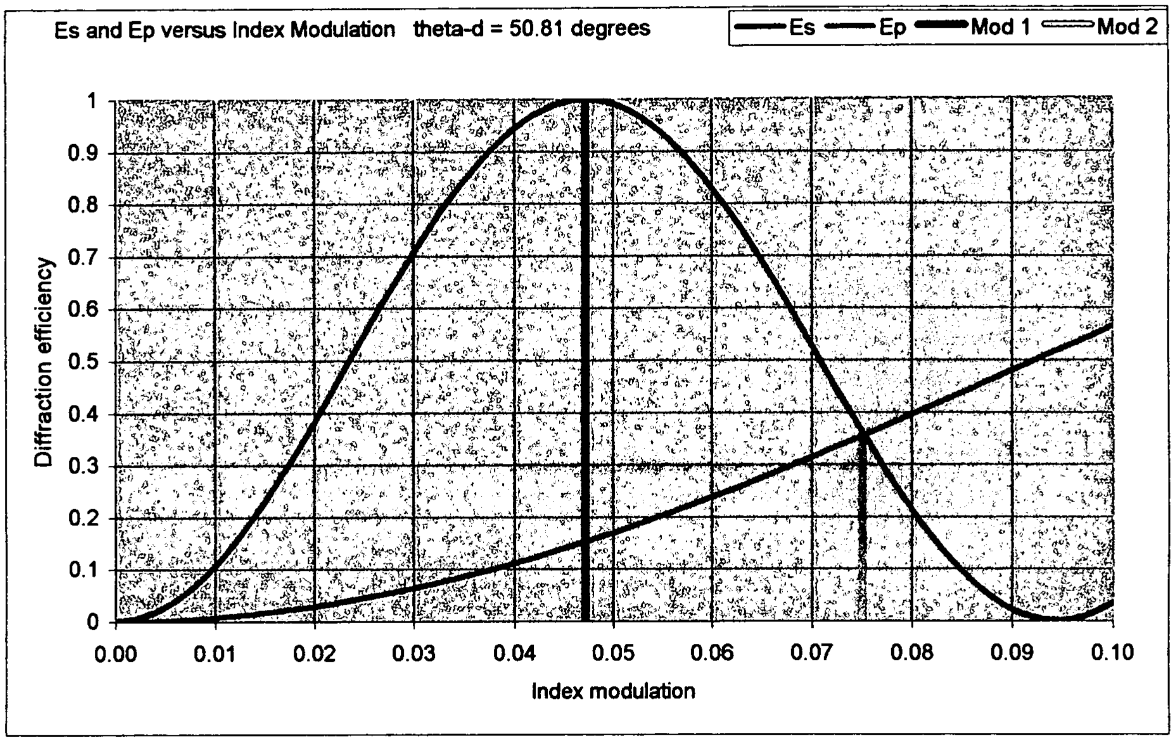

Fig. 9 S and P diffraction efficiencies versus index modulation in a high-dispersion transmission Volume Phase Grating

This VPG has an angle of diffraction of 50.81 degrees, providing a dispersion of 0.09068 degrees/nm, more than 5 x that of the VPG of Fig. 8. However, note the difference between the S and P diffraction efficiencies, no matter what value of index modulation is selected. If the index modulation indicated by the green bar is selected, the S diffraction efficiency will be 100% but the P diffraction efficiency will be only about 15%, leading to a very large PDL. If one selects the index modulation indicated by the orange bar, the two diffraction efficiencies will be equal, providing low PDL, but both diffraction efficiencies will be low - on the order of 35% - leading to a very high insertion loss (IL).

Figures 8 and 9 indicate the dilemma faced by manufacturers of VPGs for telecom applications. One can make transmission VPGs with low PDL and low IL, but such VPGs will have very low dispersion. Or one can make transmission VPGs with high dispersion, but such VPGs will have either high PDL or high IL. It has not been possible, prior to applicant's invention, to provide a high dispersion transmission VPG that also has low PDL and low IL.

As further evidence that Jannson's implied claim (that all VPGs have roughly the same S and P diffraction efficiencies) is false, consider the following figure, which is derived from a prior art US patent (PN 5,013,107).

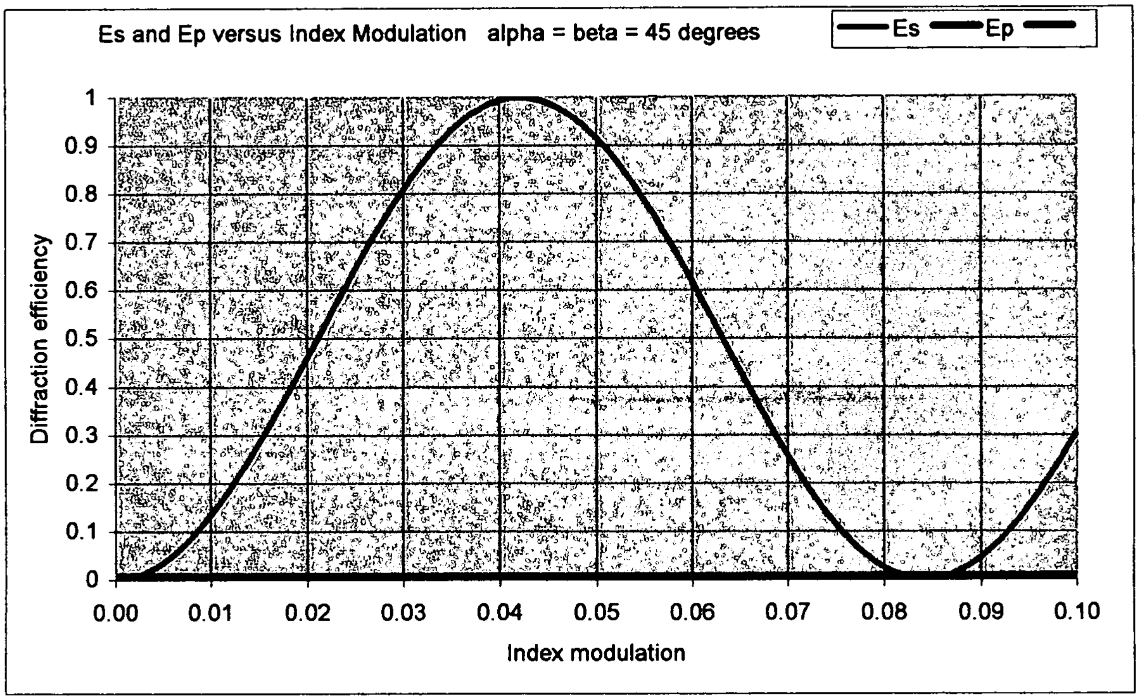

Fig. 10 S and P diffraction efficiencies versus index modulation for a transmission Volume Phase Grating in which $\alpha = \beta = 45^0$ and Ep = 0 (see PN 5,013,107)

Figure 10 shows the case where the internal angles of incidence and diffraction are both 45 degrees. In that case, $\alpha = 45$ degrees and $\alpha + \beta = 2\alpha = 90$ degrees. That is, the angle between the internal diffracted beam and the internal incident beam is 90 degrees and $\cos 2\alpha = 0$. In this case, Ep is zero no matter what the index modulation is, while Es can vary from zero to 100%. . This clearly refutes the Jannson claim that Es and Ep are roughly the same for all VPGs.

The fact that Es and Ep cannot be equal for transmission VPGs with high dispersion (large angles of incidence and diffraction) has been a limiting factor for VPGs in telecom applications that require a large number of channels. Some clever schemes have been developed to try to overcome this limitation, such as the double-pass design discussed in Patent Application 09/193,289. However, prior to applicant's invention, no one has been able to develop a single-pass transmission VPG that would provide very high dispersion with Es and Ep equal and nearly 100%.

Applicant's invention achieves high dispersion with Es = Ep = 100% by going to much higher values of index modulation - roughly 0.2, as noted in Claim 11 - and using angles of incidence and diffraction as established by the equation in Claim 9.

Figure 11 shows what happens when the index modulation is increased to roughly 0.2 and the angles of incidence and diffraction are selected using the criterion established in Claim 9. This is a graph of Es and Ep versus index modulation for one version of an Enhanced Volume Phase Grating (E-VPG) of applicant's application. In this case, the second peak of the Es curve is made to coincide with the first peak of the Ep curve. This is accomplished by letting s = 2 and p = 1 in equations 4 and 5 of applicant's original application.

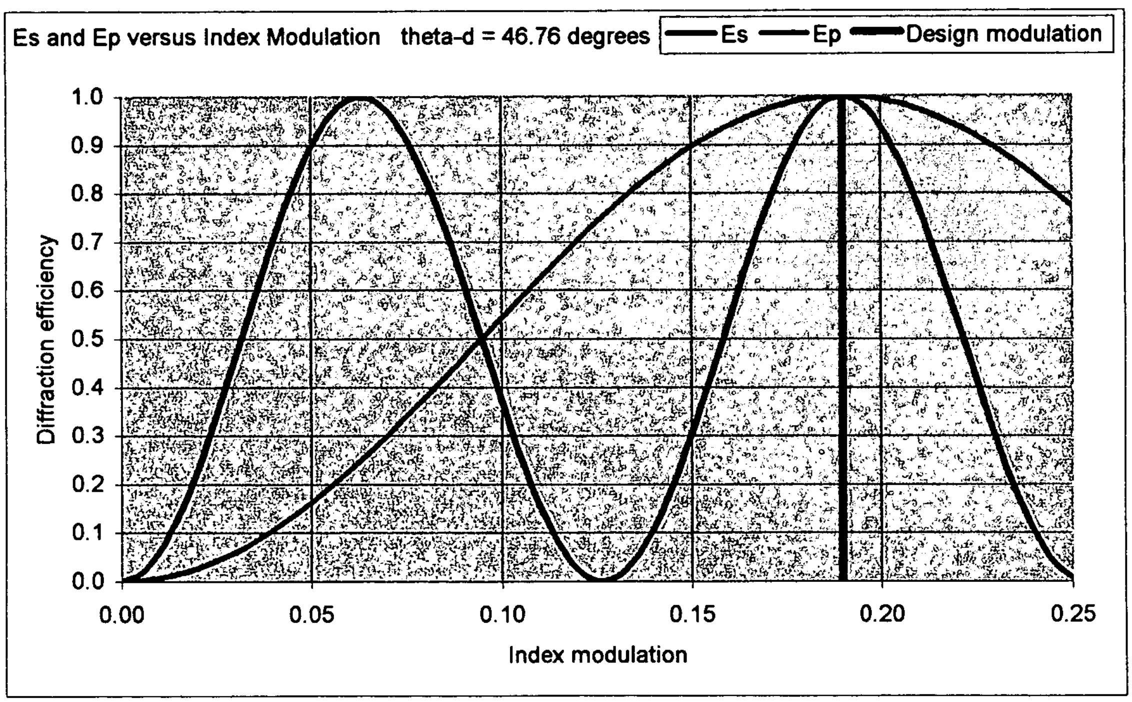

Fig.11 S and P diffraction efficiencies versus index modulation in a high-dispersion Enhanced Volume Phase Grating (T = 10 microns)

Note that at the design index modulation value of 0.19 (the green vertical bar), Es = Ep = 100%. Therefore, we have zero PDL and zero IL. At the same time, we have very high dispersion since the angle of diffraction is 46.76 degrees. For this angle, the dispersion is 0.0786 degrees/nm, or about 4.7 x the dispersion of the conventional VPG of figure 8. This combination of maximum Es and Ep with very high dispersion is a major breakthrough in the use of transmission VPGs for telecom applications.

By selecting 46.76 degrees and by using a much higher index modulation than was previously thought possible, applicant's invention provides the highly desirable combination of high dispersion and low PDL and low IL, a combination that was heretofore unavailable and unattainable.

In the example of Fig. 11, the 46.76 degrees external angle of diffraction corresponds to an internal angle of diffraction, $\beta = \alpha$, of 35.2644 degrees. An average refractive index of 1.2618 was assumed. For other values of average refractive index, the external angle of diffraction must change in order to keep the internal angle of diffraction at 35.2644 degrees. For example, for an average refractive index of 1.32, the external angle of incidence and diffraction will be 49.65 degrees and the dispersion will be 0.087 degrees per nm.

For an index modulation of 0.19 and a medium thickness of 10 microns and a wavelength of 1550 nm, the S polarization diffraction efficiency will be 1.0, as obtained from Eq. (5). For these same values of index modulation, thickness and wavelength and α = 35.2644 degrees, the P polarization diffraction efficiency will also be 1, as obtained from Eq. (9). This result is guaranteed by the selection of s = 2 and p = 1 in equation 4 of applicant's original application.

One could generalize this result by selecting any integers for the values of s and p in equation 4 of the application so long as s > p. For example, if we select s = 3 and p = 1, we get the following figure.

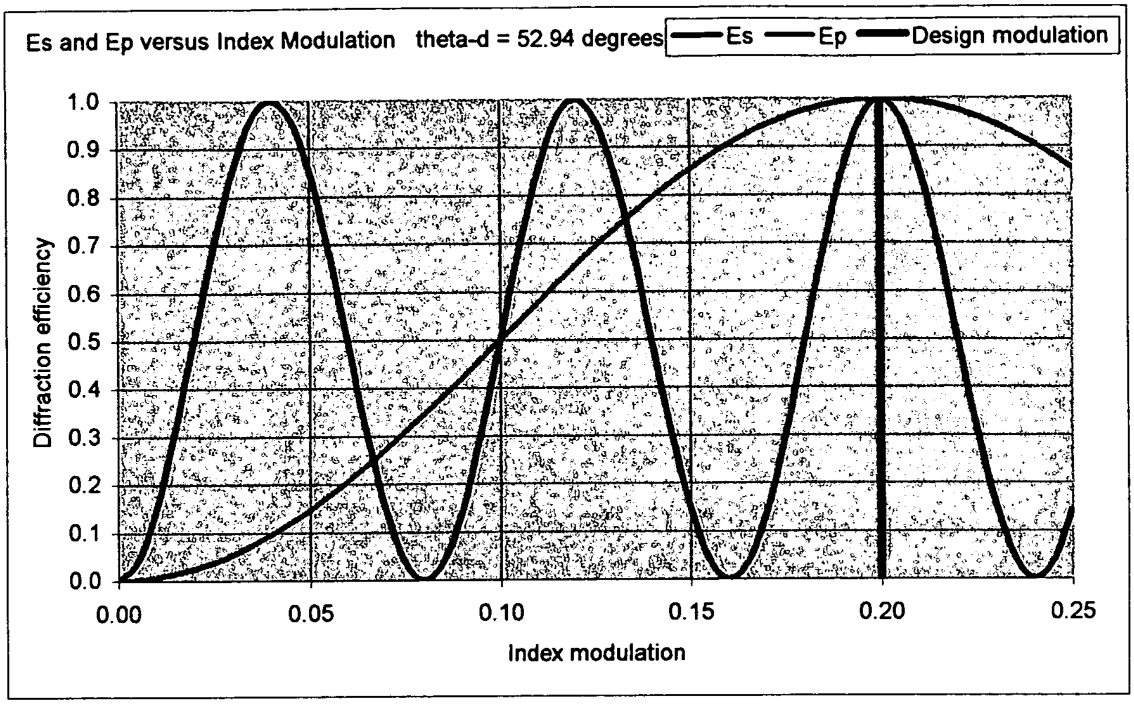

Fig.12 S and P diffraction efficiencies versus index modulation in a second version of a high-dispersion Enhanced Volume Phase Grating

Note that the angle of diffraction is now larger so that the dispersion of this E-VPG will be slightly greater than that of the previous E-VPG.

This procedure could be repeated for any values of s and p and also for the alternate equation (Eq. 6 of the application) so that the invention as described in the specification and the claims actually consists of a family of Enhanced Volume Phase Gratings, all of which will have very high dispersion and zero PDL and zero IL.

Significance of the high value of index modulation noted in Claim 11

It is possible to achieve the matching of the peaks of the S and P diffraction efficiency versus index modulation curves at lower values of index modulation by using a greater value for the thickness of the VPG medium. For example, the E-VPG of Fig. 11 has a medium thickness, T, of 10 microns. If one used a medium thickness of 40 microns, the index modulation could be reduced by a factor of four, so that the index modulation would be 0.0475, which is typical of index modulations used in prior art VPGs. The resultant graph of S and P diffraction efficiencies versus index modulation is shown in Fig. 13.

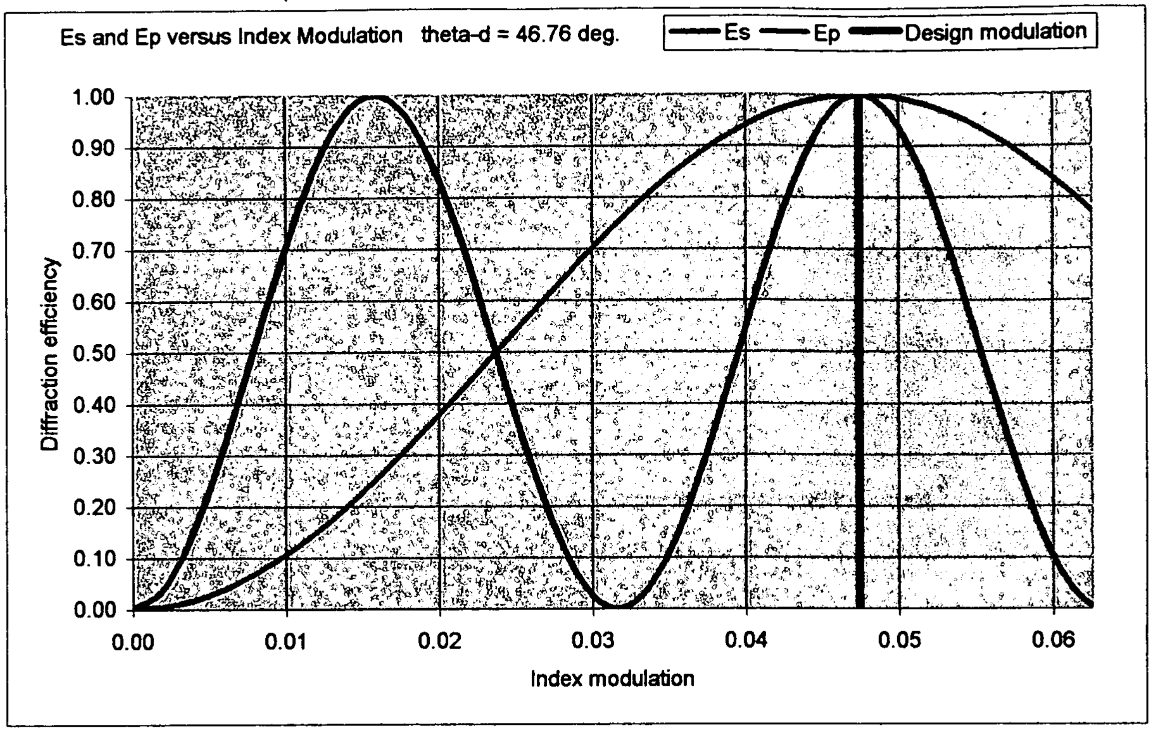

Fig.13 S and P diffraction efficiencies versus index modulation in a high thickness Enhanced Volume Phase Grating (T = 40 microns)

Note the similarity between Fig. 13 and Fig. 11. One might conclude from this similarity that one could use a lower index modulation, as is common in the prior art, accompanied by a corresponding greater medium thickness, T, and accomplish the same results that are achieved in applicant's application. However, the following two figures, which are also derived from the Kogelnik Coupled Wave Theory, show what happens to diffraction efficiency across the full width of a typical telecom band when you increase the thickness of the VPG medium to compensate for the reduced index modulation. The wavelengths in the figure run from 1530 nm to 1570 nm, which are the limits of the telecom C band.

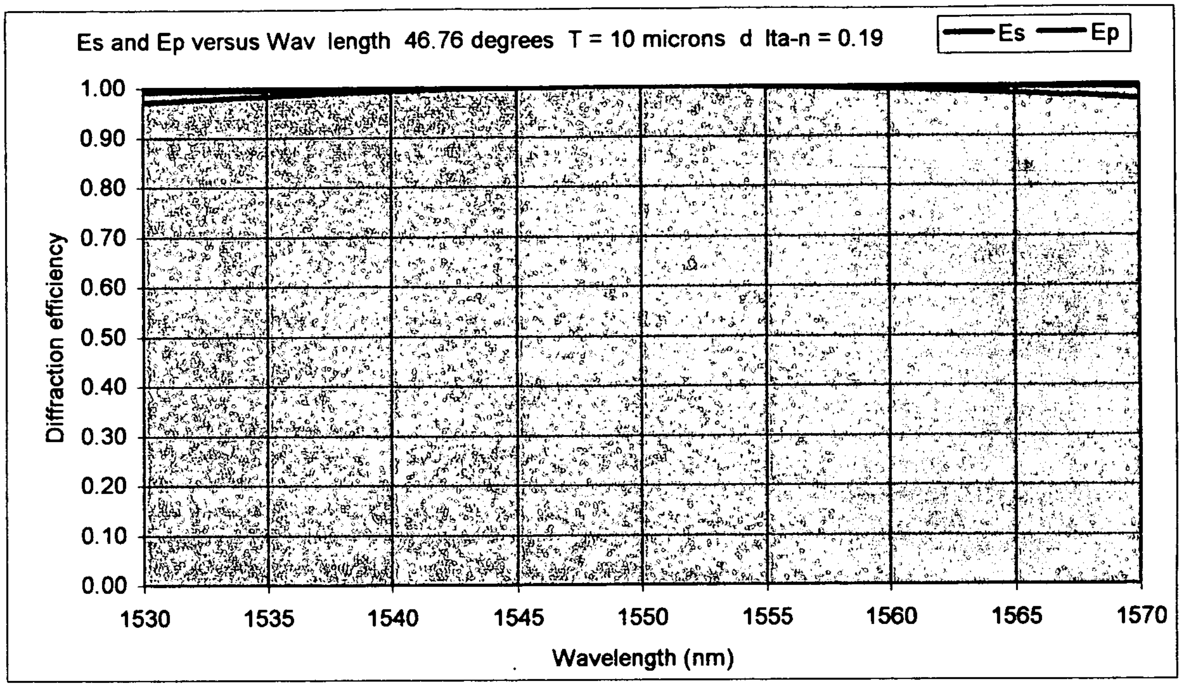

Fig.14 S and P diffraction efficiencies versus wavelength in a low thickness Enhanced Volume Phase Grating (T = 10 microns)

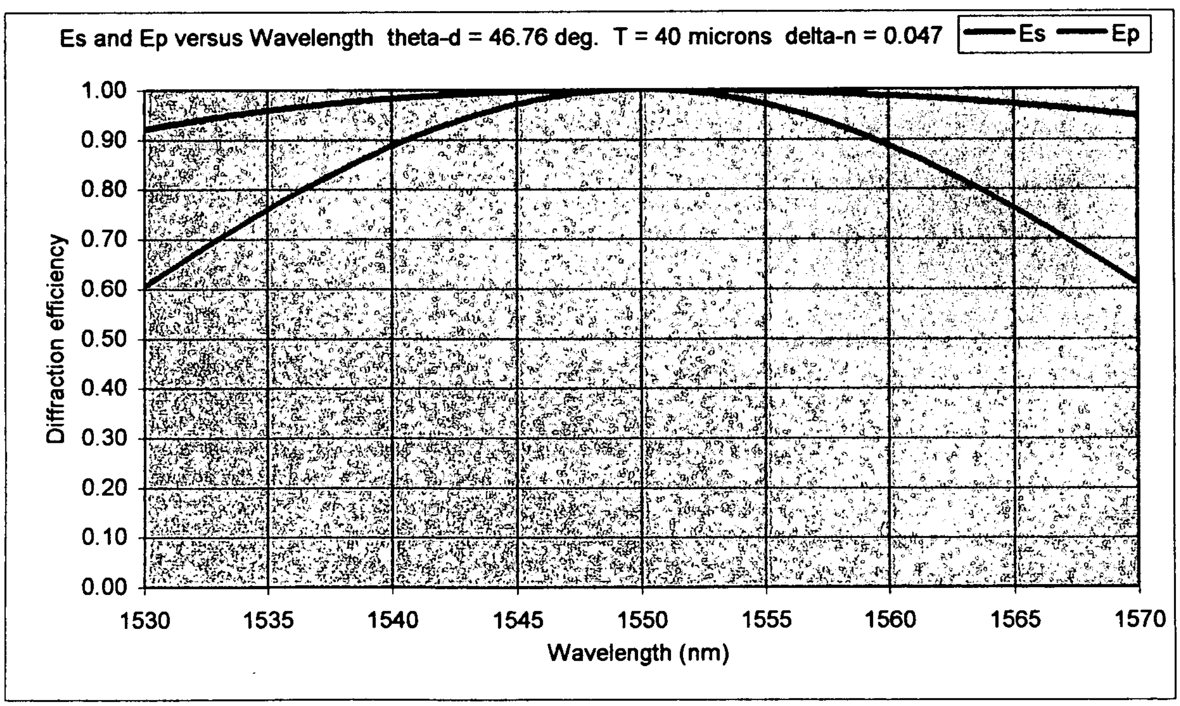

Fig.15 S and P diffraction efficiencies versus wavelength in a high thickness Enhanced Volume Phase Grating (T = 40 microns)

The advantage of the thinner medium is obvious from Figures 14 and 15. For a medium thickness of 10 microns, which would result in an E-VPG only if the index modulation was on the order of 0.2, the falloff in the S and P diffraction efficiencies at the ends of the band are negligible. However, for a medium thickness of 40 microns, as would be required to produce an E-VPG for an index modulation of 0.0475, the falloff in both the S and P diffraction efficiencies at the ends of the band are no longer negligible. In fact, this version of E-VPG is completely unacceptable because of the low P efficiency at the ends of the band, which will result in a very high PDL at the end-of-band wavelengths. Therefore, the high value of index modulation is an absolute requirement for the E-VPG and is another aspect of the novelty and uniqueness of the invention described in applicant's application.

Tutorial conclusions

In summary, Jannson's statement is valid only for low dispersion volume phase gratings, which are of little interest in the next generation, high channel-count telecom systems. For high dispersion conventional VPGs the S and P diffraction efficiencies will not be even roughly equal, except at very low values of diffraction efficiency. In fact, one of the diffraction efficiencies can be zero while the other is 100%, as shown in the tutorial herein. What is novel and unique in applicant's application, and neither anticipated nor taught in Jannson, is the creation of a new VPG (the E-VPG) in which <u>Es = Ep = 100% in a high dispersion volume phase grating.</u> Furthermore, applicant's use of a high value of index modulation (preferably on the order of 0.2) provides lower IL and lower PDL across a wide bandwidth range, as required for telecom applications.

Prior to applicant's invention of the E-VPG, no one had matched the pth peak of the Ep versus Δn curve to the sth peak of the Es versus Δn curve, as shown in Figures 11 and 12, and no one had used index modulation values on the order of 0.2 These are critical aspects of applicant's invention which allow the S and P diffraction efficiencies to both be equal to 100% at the same value of index modulation, thereby providing very low insertion loss (IL) and very low Polarization Dependent Loss (PDL) <u>across the full width of a telecom band in a VPG with very high dispersion</u> (more than 4 x the dispersion of a conventional VPG with low IL and low PDL).

Note that this coincidence of Es and Ep maxima can occur for any integer values of s and p in equations 4 and 5 of applicant's original application so long as s > p. (In Fig. 11, s = 2 and p = 1 while in Fig. 12, s = 3 and p = 1).

<u>NOTE</u>: While we have assumed, for simplification, that $\alpha = \beta$ throughout this tutorial, that is not a requirement for an Enhanced Volume Phase Grating. In fact, the selection of the internal angle of incidence, α, for an E-VPG, is completely arbitrary, as noted in Claim 9. However, once α is selected, β is fixed by the first equation of Claim 9.

The dependent claims are a fortiori patentable over Kato

Dependent claims 10 to 16 incorporate all the subject matter of the amended independent claim 9, which applicant now submits is patentable over Jannson, and they also add additional subject matter, which makes them a fortiori patentable over Kato, which does not teach the novel art of applicant's amended claim 9.

Kato teaches the use of a transparent support medium, a transparent cover medium, a transparent adhesive sealing layer and an anti-reflection coating. While by themselves these features would not be novel in applicant's invention, they become a fortiori patentable over Kato when incorporating the patentable novelty of amended claim 9.

Similarly, while Kato teaches an arrangement having a reflecting film placed at exterior surfaces of a convex lens, serving as a cover plate, the use of a reflecting element in the applicant's invention is a fortiori patentable over Kato when incorporating the patentable novelty of amended claim 9.

Conclusion

For all the reasons given above, applicant respectfully submits that the claims now comply with 35 U.S.C. 112 and 35 U.S.C. 132 and that the claims are of patentable merit under 35 U.S.C. 103(a) because of the specific novelty of creating a <u>high-dispersion</u> volume phase grating with <u>equal and maximum</u> S and P diffraction efficiencies and <u>low PDL across the full width of a telecom band</u>. Accordingly, applicant submits that this application is now in full condition for allowance.

Respectfully submitted,

Dated: June 21, 2002

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